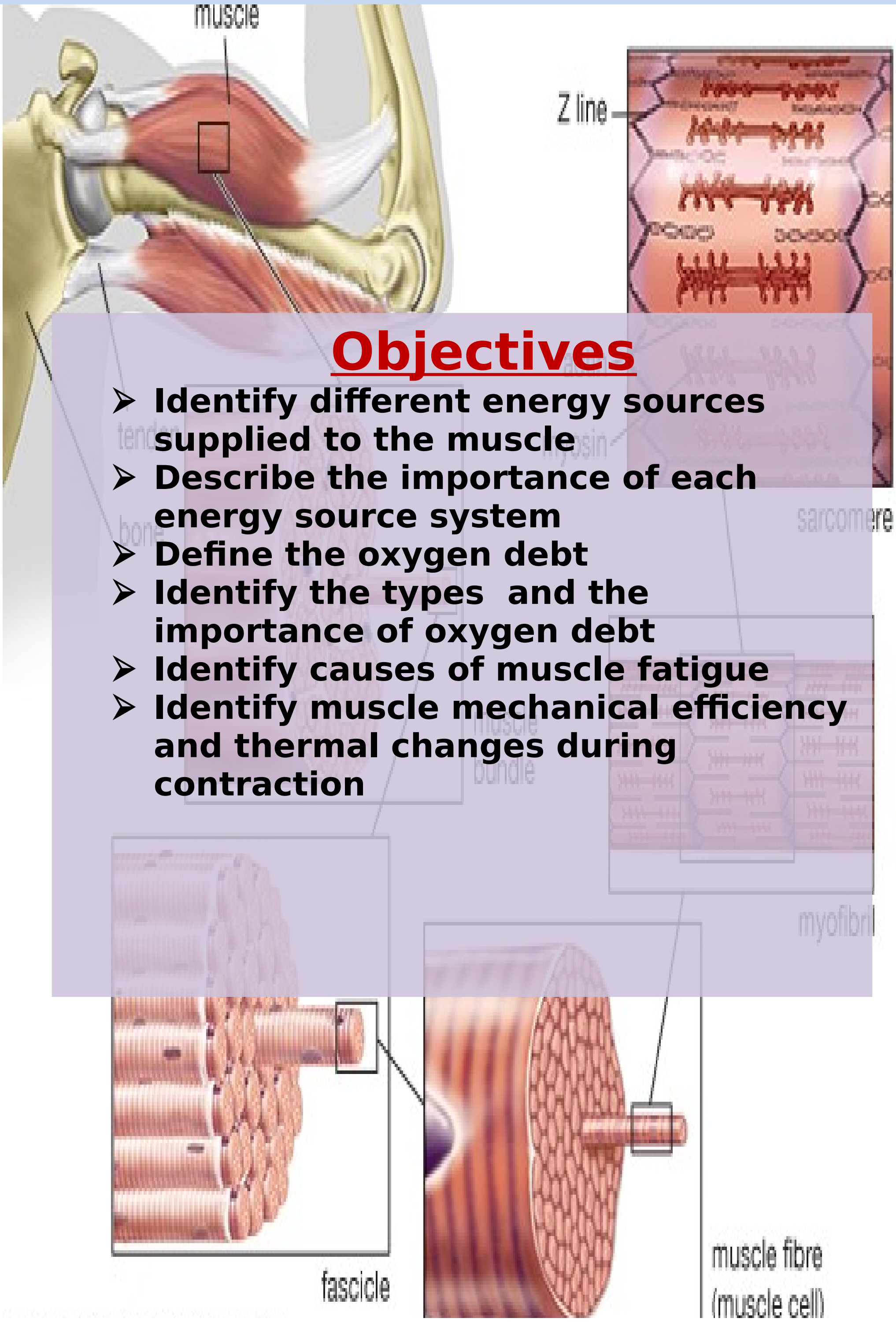
Skeletal muscle metabolism



Objectives

- Identify different energy sources supplied to the muscle
- Describe the importance of each energy source system
- Define the oxygen debt
- Identify the types and the importance of oxygen debt
- Identify causes of muscle fatigue
- Identify muscle mechanical efficiency and thermal changes during contraction

Muscle energy sources and metabolism

Muscle contraction requires energy, and muscle has been called a machine that converts chemical energy (ATP) into mechanical work.

What are the muscle energy sources?

The immediate energy source is adenosine tri-phosphate (ATP).

1- ATP:

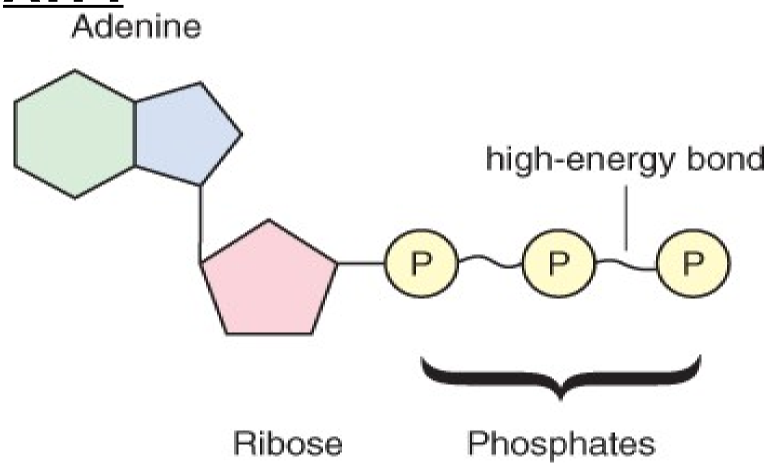


Fig (1): Adenosine tri-phosphate

- ATP is a high-energy phosphate compound and it is called the energy currency.
- Hydrolytic enzyme (ATPase) break the terminal high-energy phosphate bond to release the potential "stored" energy in ATP
- Stored ATP is minimal and sufficient only for few seconds of contraction
- Muscle contain different pathways that regenerate ATP
- Rebuilding of ADP to ATP requires a synthetic enzyme and a new source of energy to "rebuild" the high-energy bond.

2-Three pathways generate ATP

A) Ultra-rapid immediate system

- Hydrolysis of creatine phosphate.

B) Short-term anaerobic system

- Anaerobic glycolysis.

C) Long-term aerobic system

- Oxidative phosphorylation.

A) The ultra-rapid immediate system:

- At rest, extra ATP is available in the mitochondria and it transfers its phosphate to creatine forming creatine phosphate. So it builds up the energy store house.
- Creatine phosphate is three to eight times as abundant as ATP
- One molecule ATP is formed per one molecule of Creatine phosphate by substrate phosphorylation.
- It is rapidly depleted, provide immediate energy source in the first few seconds.
- Is used in High intensity short term exercise as: High jump, weight lifting and 100 m running.

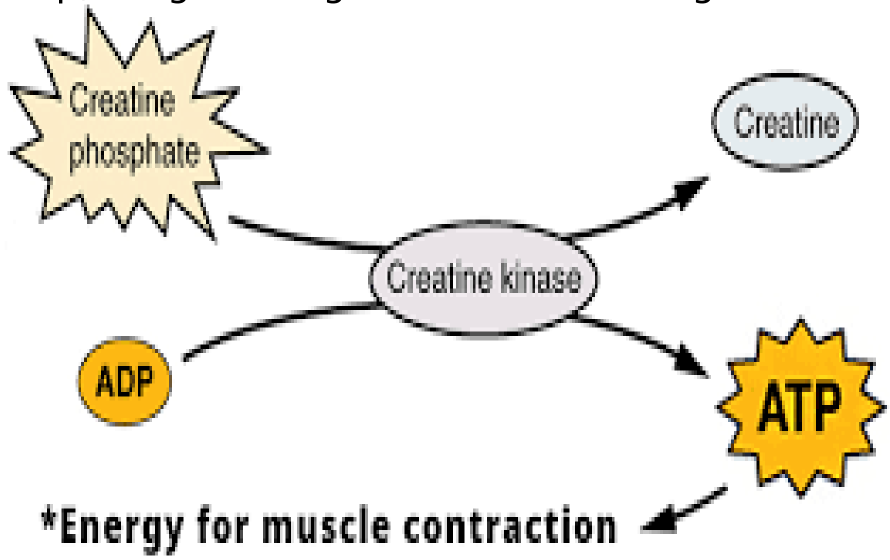


Fig (2): ATP production from creatine phosphate.

B) Short term anaerobic system:

- During exercise, glucose from blood stream or from glycogenolysis of the stored glycogen in the muscles is used as a fuel.
- In absence of oxygen glucose is metabolized by the anaerobic glycolysis producing lactic acid and 2 ATP molecules.
- This system produce ATP 2.5 times as rapid as oxidative pathways
- Few minutes at the start of exercise

- At the end of the prolonged exercise when the aerobic system fails, because excess lactic acid causes fatigue.

C) <u>Long term aerobic system:</u>

- Glucose is oxidized in the presence of oxygen that is derived directly from blood or from the stored myoglobin (the muscle oxygen containing molecule).
- This system provides energy in light exercise or prolonged aerobic endurance exercise as walking, moderate exercise, marathon and swimming.
- In prolonged light exercise more than 1 hour or in the resting muscle free fatty acids oxidation can supply energy.

<u>3- At the end of exercise:</u>

-The body shifts to anaerobic system again because the aerobic system is unable to meet the muscle demands.

- So anaerobic threshold is reached.

- Aerobic power depends on:

  - The lungs' ability to oxygenate the blood.
  - The cardiovascular system's ability to deliver the oxygenated blood to the exercising muscles.
  - The muscles' ability to extract and utilize the oxygen to produce energy.

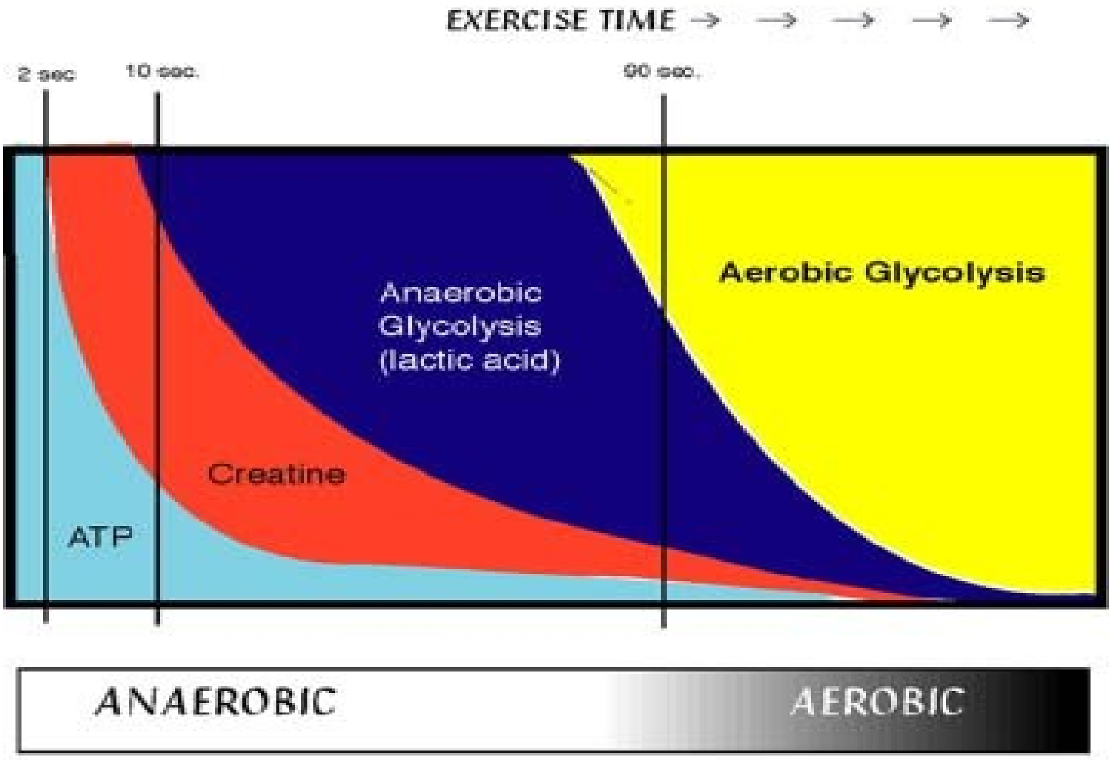


Fig (3): Dominant energy pathways for exercise of differing duration

Muscle fatigue

It is the temporary decrease in muscle force of contraction due to previous contractile activity.

- **Causes of fatigue:**
- **A) Muscular fatigue:**
  - Lactic acid accumulation: increase in the intracellular acidity and inhibit key enzymes in energy pathways.
  - Energy stores depletion
- **B) Neuromuscular fatigue:**
  - Acetyl choline depletion at the motor end plate during fast-powerful activities.
- **C) Central psychological fatigue:**
  - Central nervous system no longer adequately activates the motor neurons supplying the working muscles.

- Athlete's performance is not only dependent on the physical state of his muscles, but also, upon the well to win "ability to overcome psychological fatigue"

Oxygen debt

Definition:
Extra-amount of O_2 that must be taken into the body during recovery period after muscular exercise
Recovery period: from end of exercise till the return of heart and respiratory rate to normal.
Aim: To restore all the metabolic systems back to their full normal state.

Oxygen debt types:

alactic O_2 debt	Lactic acid O_2 debt
Smaller amount of O_2	**Greater amount of O_2**
It is fully rapid **within 2-3 minutes**	Takes about **1 hour** or more
- Replenish ATP stores - Restore creatine phosphate (CP) - Rebind to myoglobin	- Remove excess lactic acid from the muscles and all body fluid. - Convert lactic acid to pyruvic acid and glucose

Thermal changes in muscle during contraction and its mechanical efficiency

- The energy supplied to a muscle must equal its energy output.
- The energy output appears in **work** done by the muscle, in **energy-rich phosphate bonds** formed for later use, and in **heat**.
- The overall mechanical efficiency of skeletal muscle equals (**work done/total energy expenditure**).

Define mechanical Efficiency of Skeletal Muscle:

- It is the ratio of work done by the muscle in relation to total energy expenditure.
- Mechanical efficiency = Work done /Total energy expended X 100

- In isotonic contraction, normally, it averages 20 – 25%, can rise to 50% in weight lifting, It is increased by training, as in athletes
- In isometric contraction, mechanical efficiency =zero.

Thermal changes during contraction

Resting heat	**During rest** **External manifestation of basal metabolic processes.**
Initial heat	Heat in excess of resting heat during contraction **Divided into: a - activation heat** that is produced during contraction **b- shortening heat:** which is proportionate in amount to the distance the muscle shortens
Recovery heat	Heat in excess of resting heat during recovery continues for 30 min Heat liberated by the metabolic processes that restore the muscle to its pre-contraction state**= Initial heat**
Relaxation heat	**Restore muscle length after isotonic contraction**